Evolution and functional significance of derived sternal ossification patterns in ornithothoracine birds.

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Public Summary:
While it was thought that sternal ossification patterns were distinct between Enantiornithine (extinct Mesozoic avialans with teeth and clawed fingers on each wing) and Ornithodira (containing birds, nonavian dinosaurs and pterosaurs), our detailed comparisons find more similarities than were previously recognized. Based upon what is known about molecular mechanisms for morphogenesis, the parallel shifts to midline ossification appear to be related to the development of a large ventral keel, which is only present in these two lineages. Midline ossification can serve to medially reinforce the sternum at a relatively early ontogenetic stage, which would have been especially beneficial during the protracted development of the Cretaceous enantiornthines.

Scientific Abstract:
The midline pattern of sternal ossification characteristic of the Cretaceous enantiornithine birds is unique among the Ornithodira, the group containing birds, nonavian dinosaurs and pterosaurs. This has been suggested to indicate that Enantiornithes is not the sister group of Ornithuromorpha, the clade that includes living birds and their close relatives, which would imply rampant convergence in many nonsternal features between enantiornithines and ornithuromorphs. However, detailed comparisons reveal greater similarity between neornithine (i.e. crown group bird) and enantiornithine modes of sternal ossification than previously recognized. Furthermore, a new subadult enantiornithine specimen demonstrates that sternal ossification followed a more typically ornithodiran pattern in basal members of the clade. This new specimen, referable to the Pengornithidae, indicates that the unique ossification pattern observed in other juvenile enantiornithines is derived within Enantiornithes. A similar but clearly distinct pattern appears to have evolved in parallel in the ornithuromorph lineage. The atypical mode of sternal ossification in some derived enantiornithines should be regarded as an autapomorphic condition rather than an indication that enantiornithines are not close relatives of ornithuromorphs. Based on what is known about molecular mechanisms for morphogenesis and the possible selective advantages, the parallel shifts to midline ossification that took place in derived enantiornithines and living neognathous birds appear to have been related to the development of a large ventral keel, which is only present in ornithuromorphs and enantiornithines. Midline ossification can serve to medially reinforce the sternum at a relatively early ontogenetic stage, which would have been especially beneficial during the protracted development of the superprecocial Cretaceous enantiornithines.